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PRELIMINARY BEAMFORMING STUDY OF THE TFO-37 ARRAY

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Prepared For

AIR FORCE TECHNICAL APPLICATIONS CENTER
Washington, D. C.

By

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TELEDYNE, INC.

Under

Project VELA UNIFORM

Sponsored By

ADVANCED RESEARCH PROJECTS AGENCY
Nuclear Test Detection Office
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PRELIMINARY BEAMFORMING STUDY OF THE TFO-37 ARRAY

SEISMIC DATA LABORATORY REPORT NO. 216

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ABSTRACT

Beamforming of the TFO-37 array reduces the rms of the noise up to 14 db over an average single sensor, and the signal/noise improvement approaches 14 db also depending on the band pass filter used. The signal loss after beamforming and summing is approximately 1 db. Power spectra was also performed on the noise after summation as well as on individual traces and showed a 15 db reduction at 1 cps; this is an improvement of N over an average single element.

Maps, digital programs, instrument frequency response, etc. are included

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INTRODUCTION AND PURPOSE

The purpose of this report is to present a preliminary, evaluation of the new TFO array. This array consists of 37 JM short period vertical seismometers in the form of three concentric hexagons of six, twelve, and eighteen sensors each with one in the center. The approximate diameter is thirty kilometers.

In addition to presenting the results of a basic investigation, another intention is to compile all information pertaining to the array into one report which could be used as a reference for future studies.

With this in mind, a number of appendices are included consisting of the following:

Appendix	A:	Map of Array
	B:	Seismometer description and locations in latitude and longitude, etc.
	C:	Digital tape format
	D:	Digital programs written for the evaluation
	E:	Calibration parameters
	F:	Sample output from which Table 1 was prepared
	G:	JM frequency response

The primary objective is to determine the amount of signal loss, noise attenuation, and S/N gain which result from beamforming digital recordings of four teleseismic events. The LASA Bulletin statistics for these earthquakes are shown in Table 2. Since this report includes such a small sampling of events, one from each quadrant was selected to give full azimuthal coverage.

PROCEDURE

Digital seismograms are recorded at the site on 7-track magnetic tape in multiplex form at the rate of 556 bpi. Sine wave calibrations (1 cps) are performed daily on each data channel.

Each seismogram used in this study is detrended, thereby removing mean, and each was converted from digital counts to equivalent earth motion (mu) at 1 cps. For comparative purposes processing was accomplished twice using different band pass filters. One has a cut-off at .4 - 3 cps, the common LASA or SDL filter, while the other cuts off at .7 - 5 cps and will, hereafter, be referred to by the designation Fc. Both fall off at the rate of about 24 db/octave (Figure 1); however, since the phase angle of the data was preserved, the effective decay rate becomes 48 db/octave. As can be immediately seen, the Fc filter removes considerably more of the low frequency microseisms, the effect of which will be perceived in the results.

The seismograms were then time-shifted to align P arrivals by applying computed travel time differences. No attempt was made to fit by any other method.

Selected portions of the multiplexed data amounting to two minutes of noise and one minute of signal were demultiplexed and converted to SDL library format. The resulting data were combined under one label and input to the beamforming program. Calibrations were also converted to the format under several labels but were fed directly to the magnification program. Outputs from this program were saved on punched cards and printouts. Quality control has been limited primarily to the elimination of dead or reversed traces.

RESULTS

Table 1 contains the final results of the amplitude analysis and contains three major headings under Signal, Noise and S/N. Although the table is self-explanatory, a few of the salient features can be mentioned. Relative to the signal there is a slight loss in amplitude between the mean and the sum as expected possibly due to small mis-alignments. In addition, the apparent db loss can also be attributed to the signal/noise ratio. The Tunisia earthquake is poorly recorded and the "p" probably contains some noise which precludes an accurate estimate of signal amplitude during the phasing process. A deterioration in amplitude (mu) is obvious between the SDL and Fc filter by about 4 db in all cases. This suggests that the SDL filter is more effective in preserving signal amplitude within the frequency range of the events studied. On the other hand, an examination of Figure 2 reveals the undersirable loss of first motion as well as a loss of signal character caused by the SDL filter. The SDL filter appears to over-simplify the signature at the same time. This retrogression is due to the low frequency of the recorded signal which is well down in db from the .4 cps low cut-off.

With respect to the noise, both filters have an acceptable reduction in rms but the Fc is the better of the two. This is due to the removal of the low frequency microseisms which predominate. The amplitude of the maximum noise excrusion, indicated by the heading RANGE, is also shown. The ratio of the Range/rms is approximately 3/1, a value normally considered when referring to peak vs average rms.

The last heading in the table is probably the most crucial, statistically speaking, since it deals with the all-important S/N ratio. Again, both filters function well but the Fc responds

best by about 3 db over the SDL. However, neither equals, on the average, the $\sqrt{N}$ criterion.

Again, regarding the Signal portion of the table, it may be found that alignment of the P phase is best achieved either by using average observed travel-time anomalies, or by phasing using cross-correlations.

Power spectra was also performed on the noise of the four events by a digital program based on the Blackman and Tukey method. Figures 3 and 7 illustrate the results of spectral analysis on 100 seconds just prior to the signal of the phased sum of all channels vs. the average spectra of outputs recorded by 18 to 19 spatially selected individual elements. It was felt that taking the average of a number of sensors was somewhat better than selecting just one and that spatial sampling of the array would give about the same results as processing the total.

As to be expected, the spectral shape is approximately the same for any given filter and will not vary too much whether the analysis is performed on an individual trace or the phased sum of many. In all examples shown, summing the elements attenuates the noise at, for example, 1 cps approximately 15 db over the average single instrument which is equal to a factor of N. The best S/N ratio, again referring to Table 1, is several db lower. For comparative purposes, Figure 3 shows the results of raw data processing of the Hokkaido event. This reveals that the lower frequencies are basically coherent across the array and are preserved even after time shifting. Where normally the peak power occurs at just under 1 cps after filtering, the peak on raw data is at about 0.25 cps.

SUMMARY

The results of this basic study revealed several prominent features:

1) The P phase from strongly recorded events is attenuated only slightly by beamforming. However, it appears that the weaker the event the greater the loss.

2) The rms of the noise is reduced by 11-14 db, depending on the filter, after summing.

3) The zero-to-peak maximum noise excursion in mu is about 3 times that of the average rms obtained in a 100 second window.

4) There is also an 11-14 db improvement in S/N ratio by beamforming.

5) There is an approximate 15 db noise reduction at 1 cps as shown by the power spectra.

6) Neither filter used is completely satisfactory. The SDL seems to preserve signal amplitude at the expense of character but does not reduce the noise to a minimum. The Fc filter reduces the noise almost to the system background, but attenuates the signal amplitude while preserving the first motion and shape.

RECOMMENDATION

As a result of this study, three areas of interest were found which should be investigated; they are:

1) The use of average observed travel-time anomalies and cross-correlations to reduce beamforming signal loss.
2) The design and evaluation of a set of band-pass filters to determine the most efficient with respect to signal preservation and noise reduction.
3) The comparison of TFO-37 with LASA, NORSAR and the other arrays in terms of their respective detection and identification capabilities.

Table 1. TFO-37 amplitudes for data prefiltered 0.4 - 3 and 0.7 - 5 cps

TFO-37 Amplitudes for Data Prefiltered 0.4 - 3 cps

EVENT	DATE	M_S (db)	SIGNAL			NOISE							S/N						REMARKS
			mμ		db	mμ		db	mμ		db		S/RANGE			S/RMS			
			MEAN	Σ	Σ/MEAN	RMS	Σ	Σ/RMS	RANGE	Σ	Σ/RANGE	RANGE/RMS	MEAN	Σ	Σ db/MEAN	MEAN	Σ	Σ db/MEAN	
HOKKAIDO	25 FEB 68	15	13.9	13.3	0	0.44	0.13	-10	1.33	0.36	-11	3.1	10.4	36.8	+11	29.7	100.7	+11	N=34
SO.PACIFIC	24 FEB 68	15	32.4	31.4	0	0.41	0.12	-11	1.38	0.30	-13	3.3	25.7	106.2	+12	72.6	258.1	+11	N=34
PERU	24 FEB 68	15	2.9	2.5	-1	0.43	0.11	-12	1.28	0.40	-10	3.0	2.3	6.4	+ 9	6.1	23.6	+12	N=31
TUNISIA	25 FEB 68	15	2.7	2.4	-1	0.43	0.13	-11	1.36	0.43	-10	3.1	2.0	5.7	+ 9	5.5	19.2	+11	N=33
TFO Amplitudes for Data Prefiltered 0.7 - 5 cps																			
HOKKAIDO	25 FEB 68	15	9.2	8.5	-1	0.23	0.04	-14	0.77	0.15	-14	3.4	12.4	56.8	+13	37.8	196.2	+14	N=34
SO.PACIFIC	24 FEB 68	15	20.6	19.8	0	0.23	0.04	-14	0.99	0.19	-14	4.0	28.2	105.9	+11	84.3	449.0	+15	N=34
PERU	24 FEB 68	15	2.1	1.0	-1	0.25	0.05	-14	0.80	0.14	-15	3.2	2.8	14.3	+14	7.9	40.3	+14	N=31
TUNISIA	25 FEB 68	15	1.4	1.1	-2	0.24	0.05	-14	0.79	0.15	-15	3.3	1.9	7.7	+12	5.2	22.8	+13	N=33

Table 2. LASA bulletin statistics for four teleseismic events

DATE	EVENT NAME	MAG	LAT	LONG	ORIGIN TIME	TFO TAPE NO.
25 FEB 68	HOKKAIDO	5.4	44.5 N	141.7 E	10:25:43.0	378
24 FEB 68	SO.PACIFIC	5.1	35.0 S	169.8 W	01:11:27.0	364
24 FEB 68	PERU	5.0	16.3 S	71.7 W	07:31:28.0	367
25 FEB 68	TUNISIA	4.8	36.0 N	10.8 E	15:40:28.0	380

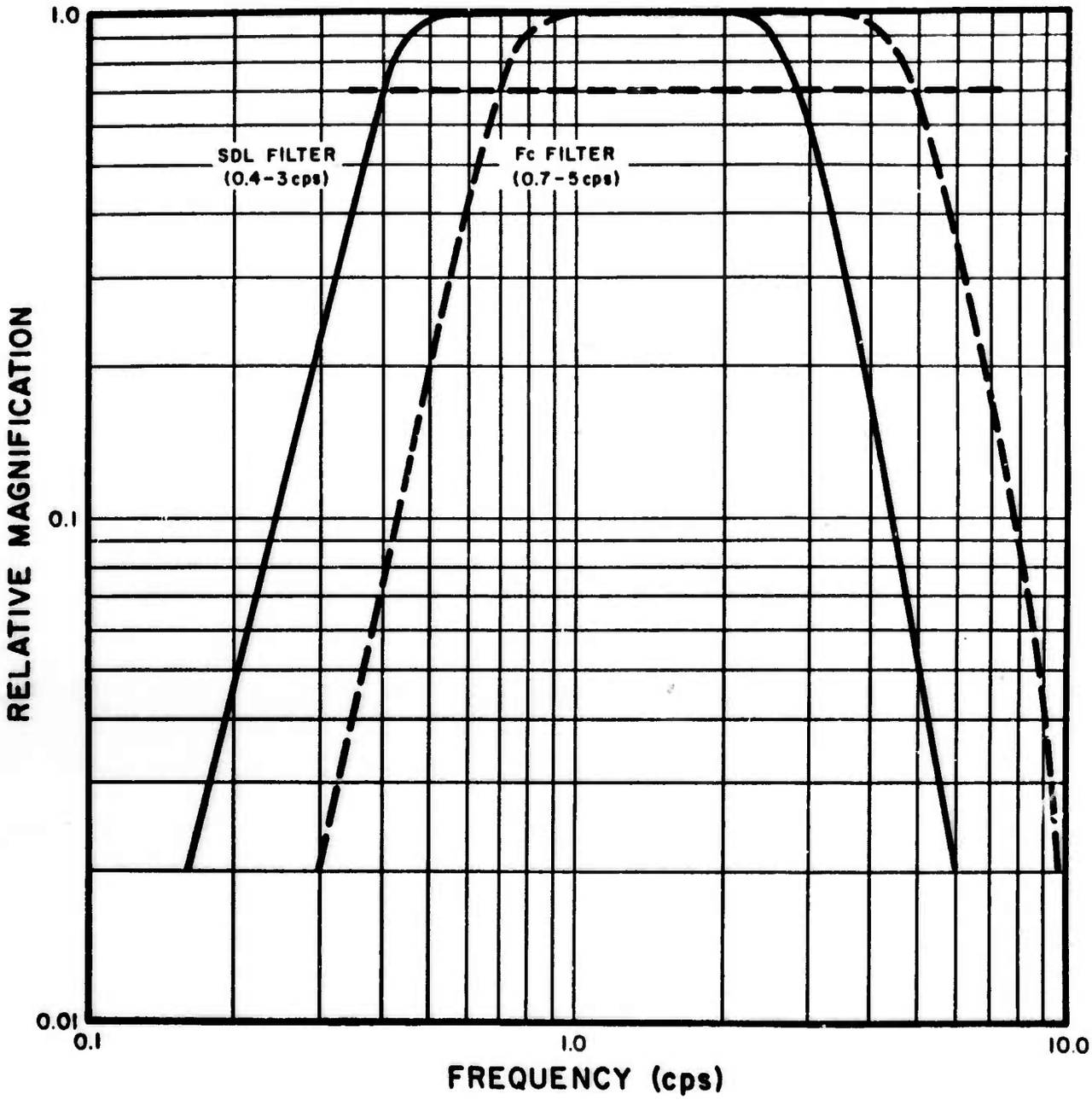


Figure 1. Bandpass filters used in data preparation.

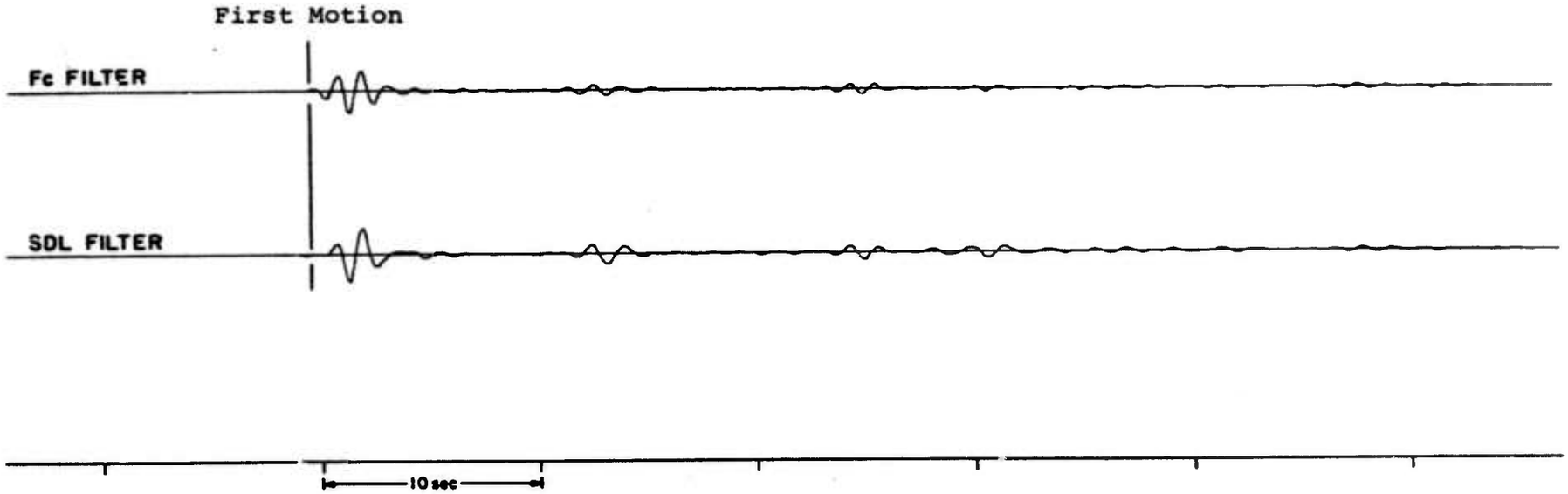


Figure 2. Earthquake, South Pacific, 24 February 1968, phased sum.

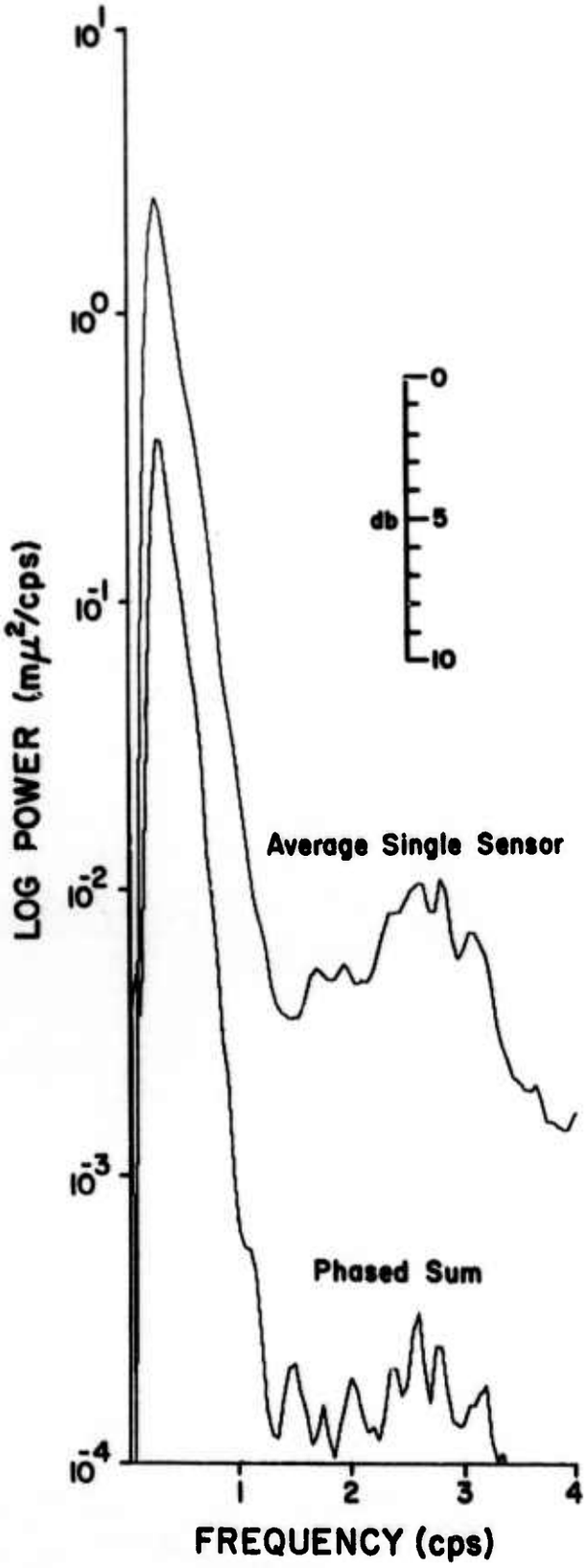


Figure 3. Power spectra of unfiltered noise Hokkaido, 25 February 1968.

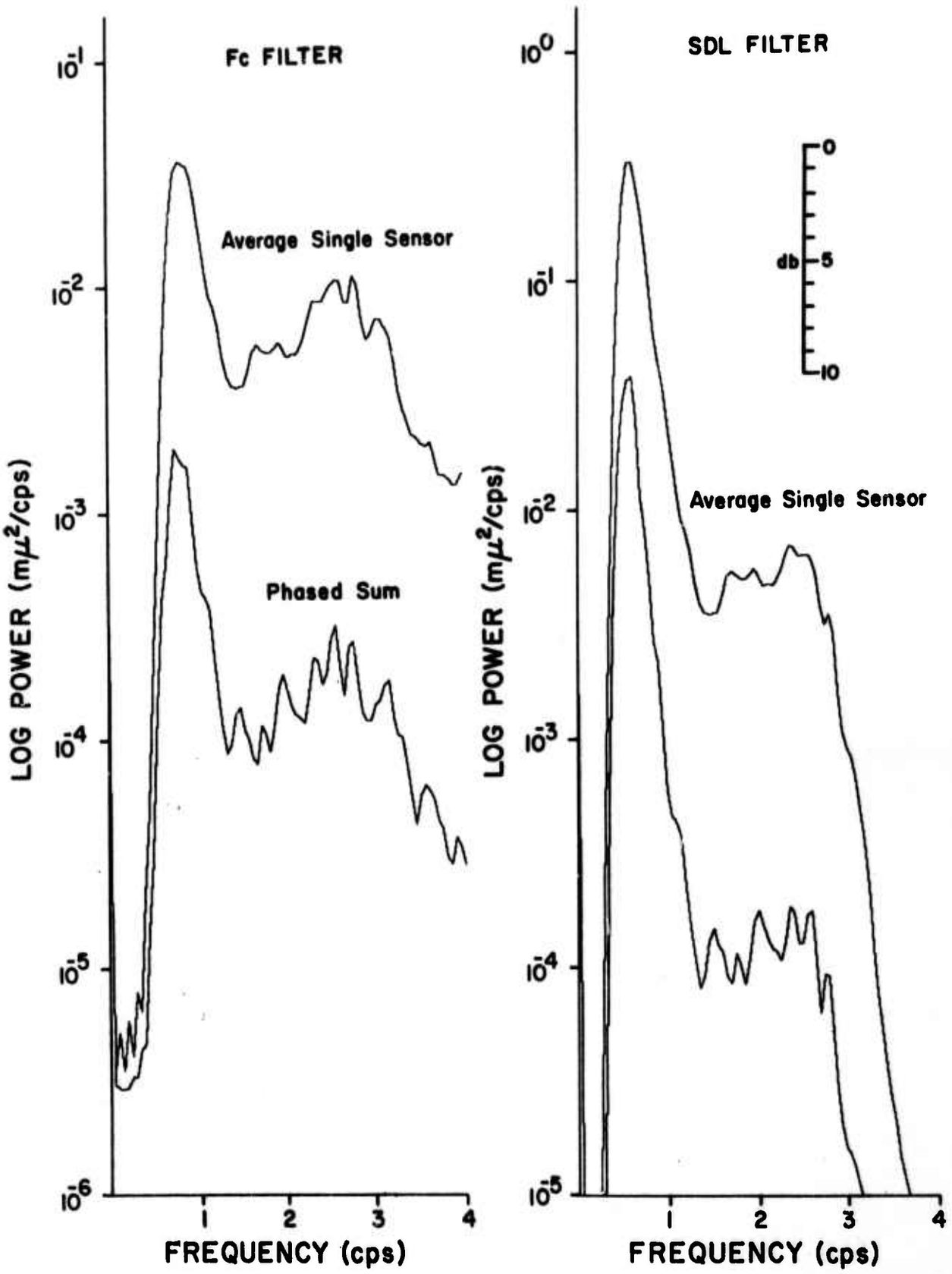


Figure 4. Noise power spectra, Hokkaido, 25 February 1968.

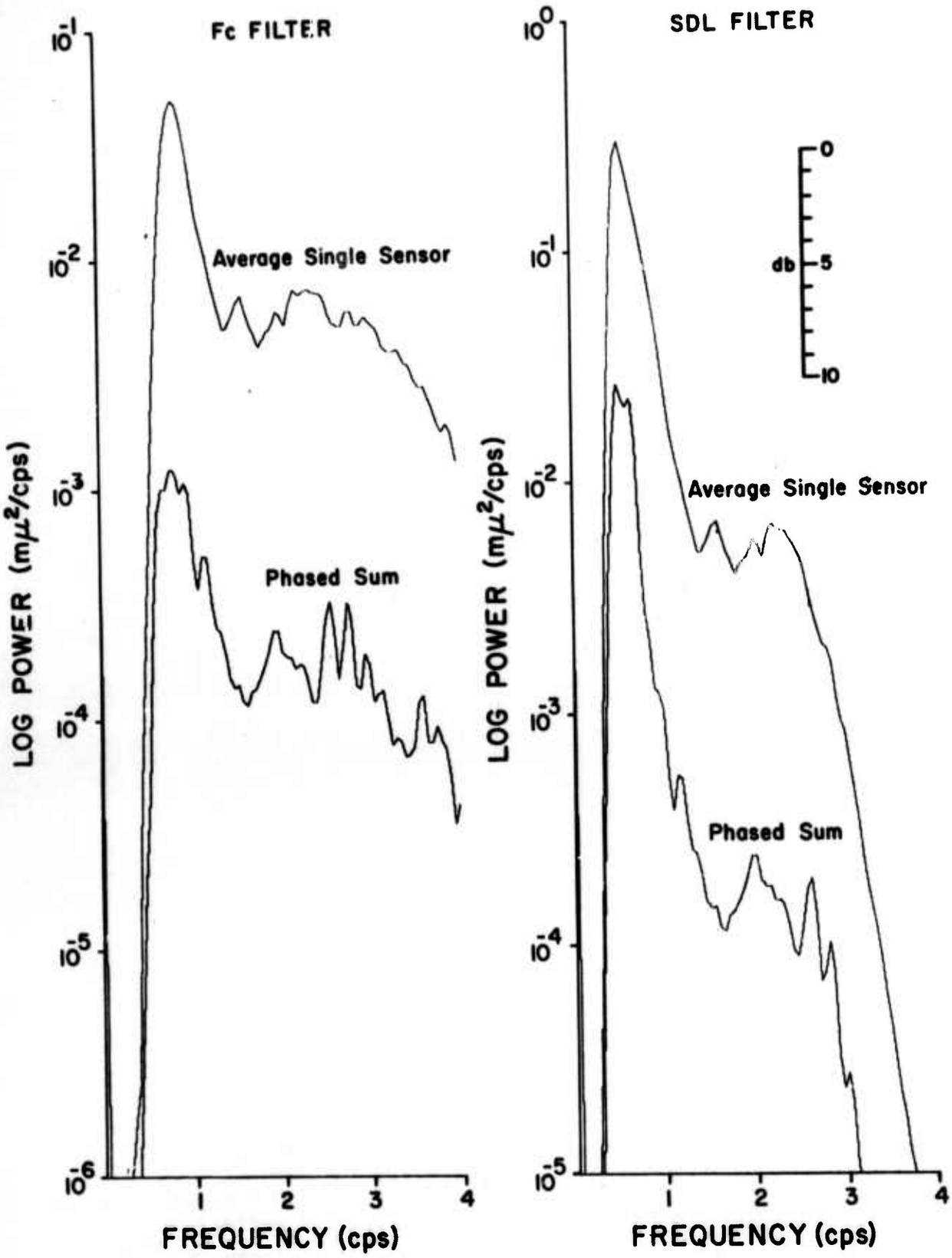


Figure 5. Noise power spectra, South Pacific, 24 February 1968.

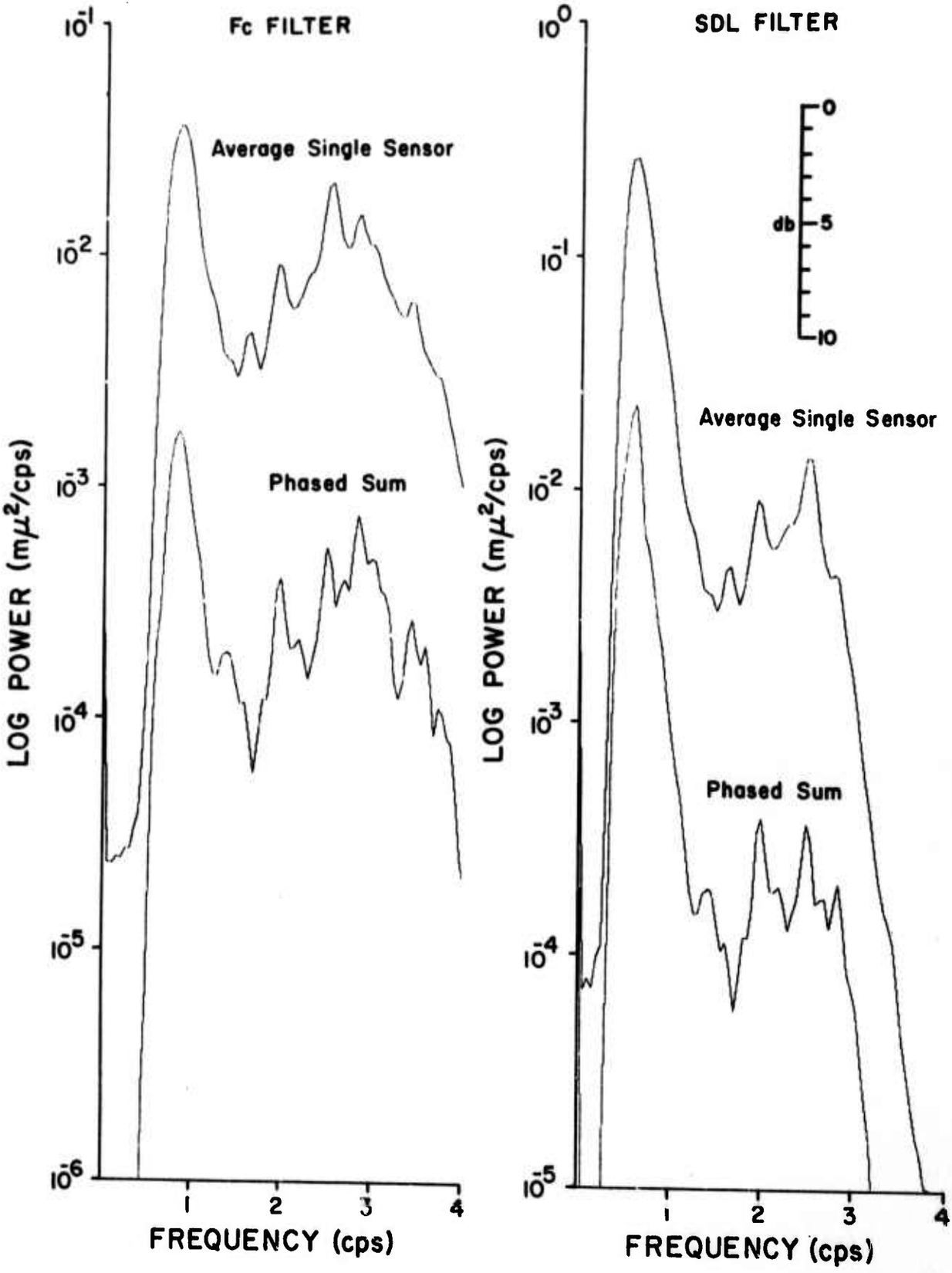


Figure 6. Noise power spectra, Peru, 24 February 1968.

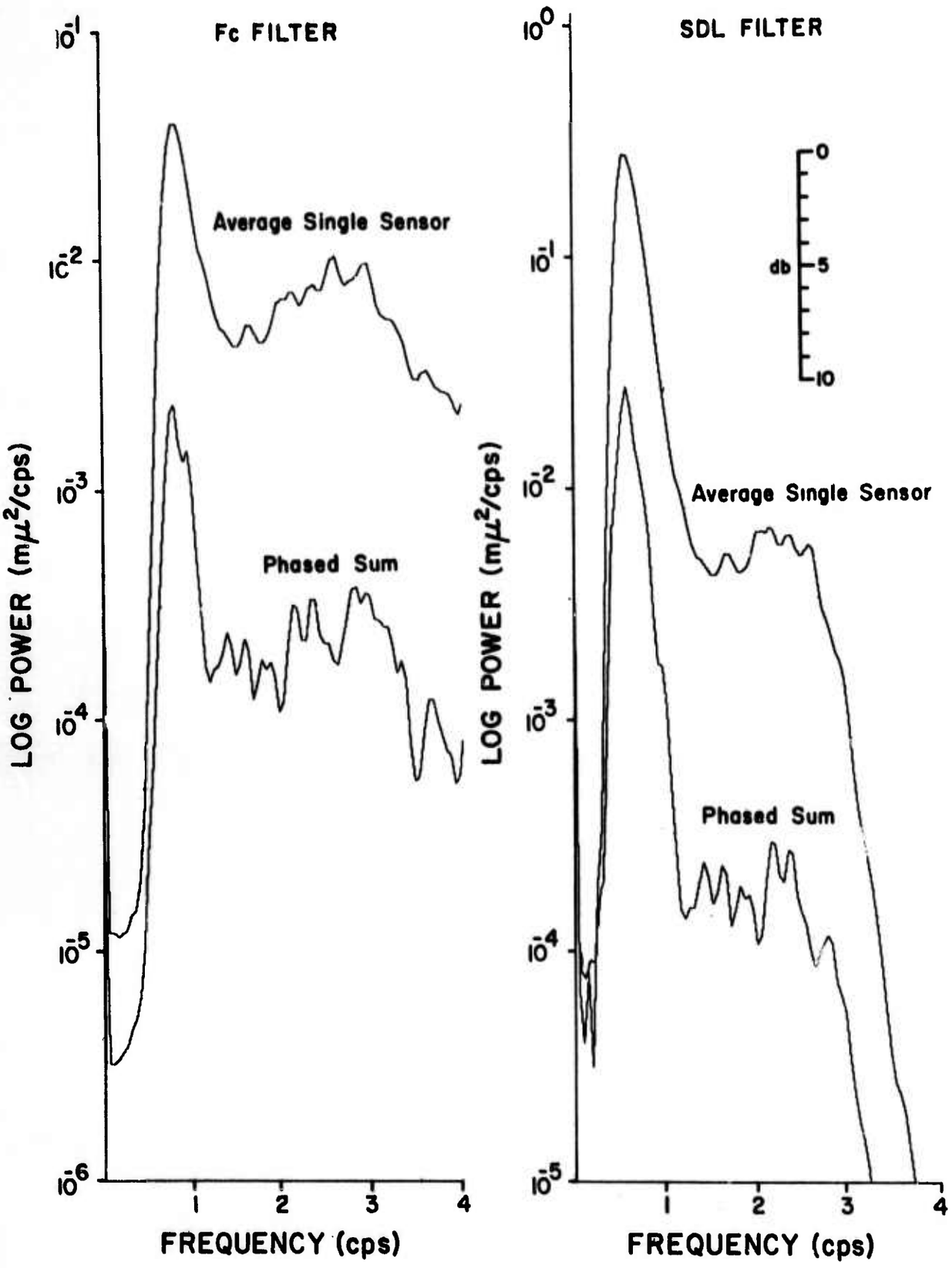
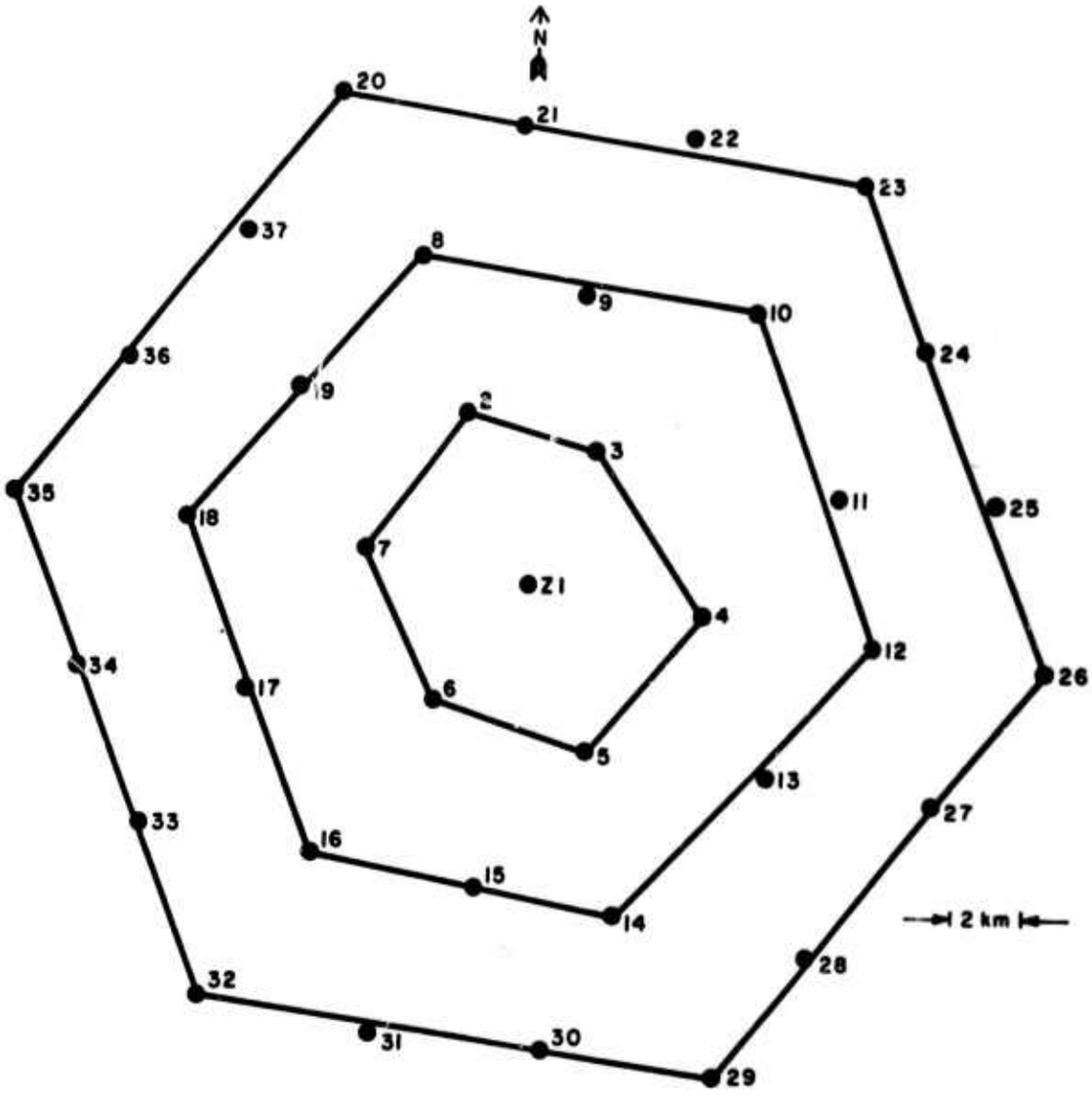


Figure 7.. Noise power spectra, Tunisia,
25 February 1968.

APPENDIX A

Tonto Forest Seismological Observatory
37 element array



APPENDIX B

Seismometer descriptions and locations
Tonto Forest Seismological Observatory

TONTO FOREST SEISMOLOGICAL OBSERVATORY - 37 ELEMENT ARRAY

	LAT	LONG	LAT	LONG	Y	X	ELEVATION METERS	ELEVATION FEET
E-1	34 16 42.3300N	111 18 12.2560W	34.27842	-111.30340			1615.42	5299.94
E-2	34 19 14.1190N	111 19 26.6720W	34.32059	-111.32408	4.68838	-1.89929	1489.75	4887.62
E-3	34 18 42.5760N	111 16 56.0730W	34.31183	-111.28224	3.71410	1.94439	1515.3	4971.47
E-4	34 16 13.8910N	111 14 56.7380W	34.27053	-111.24909	-.87841	4.99014	1474.6	4837.79
E-5	34 14 10.2220N	111 17 2.2670W	34.23617	-111.28396	-4.69824	1.78631	1491.9	4894.82
E-6	34 14 55.6970N	111 20 7.0030W	34.24880	-111.33528	-3.29363	-2.92865	1509.4	4952.1
E-7	34 17 9.1830N	111 21 24.5490W	34.28588	-111.35682	.82942	-4.90783	1403.2	4603.74
E-8	34 21 42.2900N	111 20 23.5360W	34.36175	-111.33987	9.26501	-3.35062	1805.4	5923.216
E-9	34 21 10.0020N	111 17 12.9640W	34.35278	-111.28693	8.26772	1.51329	1569.4	5149.92
E-10	34 20 52.2090N	111 14 4.9130W	34.34784	-111.23470	7.71814	6.31285	1658.5	5441.31
E-11	34 18 4.8650N	111 12 23.8630W	34.30135	-111.20663	2.54930	8.89192	1904.9	6244.96
E-12	34 15 49.5070N	111 11 44.7380W	34.26375	-111.19576	-1.63157	9.89049	1528.29	5014.07
E-13	34 13 48.4020N	111 13 48.3160W	34.23011	-111.23009	-5.37220	6.73645	1513.74	4966.34
E-14	34 11 41.4430N	111 16 30.2940W	34.19485	-111.27508	-9.29365	2.20234	1534.0	5032.64
E-15	34 12 8.0760N	111 19 8.4440W	34.20224	-111.31901	-8.47102	-.43407	1487.4	4879.91
E-16	34 12 32.0810N	111 22 13.9550W	34.20891	-111.37054	-7.72957	-6.16880	1462.9	4799.67
E-17	34 15 3.9540N	111 23 28.2740W	34.25110	-111.39119	-3.03859	-8.06562	1426.4	4679.89
E-18	34 17 40.6760N	111 24 39.9530W	34.29469	-111.41110	1.80834	-9.89511	1664.9	5462.34
E-19	34 19 39.8540N	111 22 32.4010W	34.32774	-111.37567	5.48327	-6.63959	1588.55	5211.76
E-20	34 24 9.1310N	111 21 53.2950W	34.40254	-111.36480	13.80057	-5.64150	1681.5	5516.65
E-21	34 23 37.5740N	111 18 26.3570W	34.39377	-111.30732	12.82585	- .35990	1689.6	5543.27
E-22	34 23 28.8320N	111 15 15.7050W	34.39134	-111.25436	12.55583	4.50605	1737.6	5700.70
E-23	34 22 49.9350N	111 12 3.3500W	34.38054	-111.20093	11.35440	9.41546	1887.8	6193.48
E-24	34 20 19.7490N	111 10 50.2150W	34.33882	-111.18062	6.71553	11.28206	1782.2	5847.13
E-25	34 18 .1330N	111 9 27.7090W	34.30004	-111.15770	2.40314	13.38784	1760.5	5775.96
E-26	34 15 26.0790N	111 8 32.8140W	34.25724	-111.14245	-2.35520	14.78890	1793.5	5884.23
E-27	34 13 17.2600N	111 10 34.3090W	34.22146	-111.17620	-6.33410	11.60803	1632.8	5356.86
E-28	34 11 6.0320N	111 12 54.1100W	34.18501	-111.21503	-10.38740	8.11993	1304.1	4278.48
E-29	34 9 15.9990N	111 14 36.3650W	34.15444	-111.24343	-13.78605	5.51011	1191.6	3909.49
E-30	34 9 38.0400N	111 17 47.7620W	34.16057	-111.29660	-13.10526	.62515	1531.3	5023.82
E-31	34 9 53.4040N	111 21 4.7360W	34.16483	-111.35132	-12.63070	-4.40215	1289.6	4231.03
E-32	34 10 27.0800N	111 24 18.6990N	34.17419	-111.40519	-11.59053	-9.35260	1162.9	3815.44
E-33	34 12 57.2160N	111 25 29.7490W	34.21589	-111.42493	-6.95321	-11.16599	1233.0	4045.33
E-34	34 15 27.4360N	111 26 45.8330W	34.25762	-111.44606	-2.31329	-13.10785	1229.7	4034.33
E-35	34 18 1.6300N	111 27 59.3110W	34.30045	-111.46648	2.44938	-14.98321	1499.1	4918.33
E-36	34 20 2.5200N	111 25 49.2930W	34.33403	-111.43036	6.18337	-11.66480	1601.1	5253.08
E-37	34 22 4.9590N	111 23 34.0940W	34.36804	-111.39280	9.96520	-8.21416	1722.4	5651.06

APPENDIX C

Digital tape format *

The TFSO digital recordings are written on 7-track IBM compatible magnetic tape.

1. DEFINITIONS

1.1 DATA WORD

A 36-bit word containing three samples of data from three different seismographs. Sources (seismometers) are identified as channel "i" where i is the detector identity and $1 \leq i \leq 48$.

1.2 TIME WORD

A 36-bit word which contains clock samples in milliseconds and the time the clock was reset to zero from 0000Z.

1.3 SCAN

Equal to sixteen data words, i.e., one data sample from each of 48 seismographs.

SCAN = (16 data words) (3 samples per data word) = 48 samples.

The real time required for a scan is approximately 50 milliseconds. The scans alternate starting times to synchronize the input with the output. The scans are started at intervals of 48 and 52 milliseconds in the following sequence:

0, 48, 100, 148, 200, 248, 300, 348, 400, etc.

*After Geotech

1.4 DATA RECORD

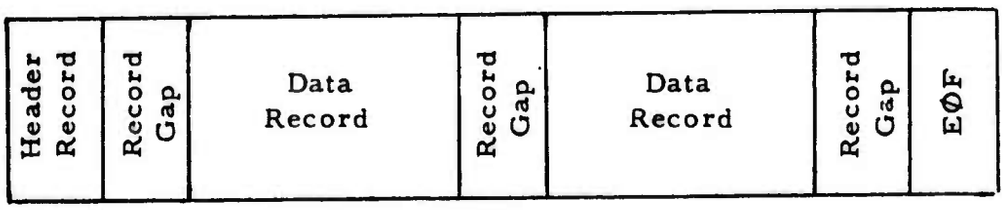
Consists of one Time Word and 220 Scans. All the data for all channels for a 11 second sample period (220 data samples from each seismometer). Data Record = (220 scans) (16 data words per scan) + (1 time word) = 3,521 thirty-six bit words.

1.5 HEADER RECORD

An auxiliary record containing only 36 bits. It is the first record of each tape. (If there is more than one file, it is the first record of each file.) The data on this record includes the date, format designation, and the Astrodata amplifier gain settings.

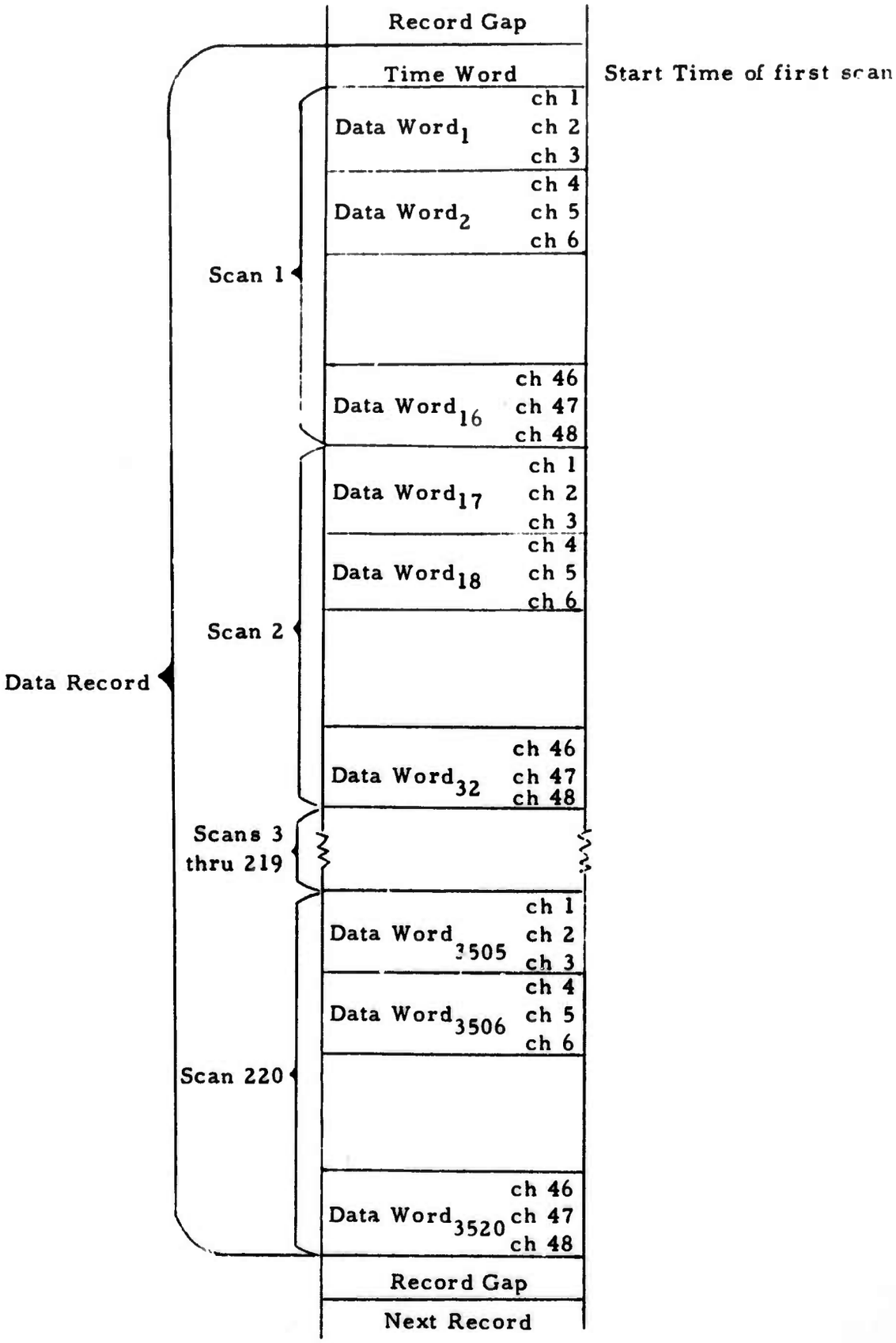
2. FORMATS

2.1 OVERALL FORMAT

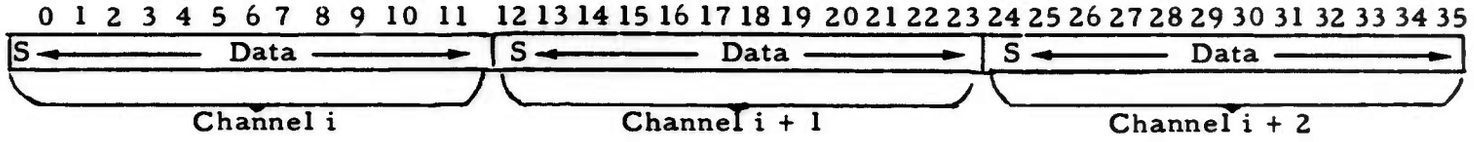


A Tape can record approximately 2 hours and 20 minutes of data with each data record being 11 seconds of data.

2.2 FORMAT OF EACH DATA RECORD

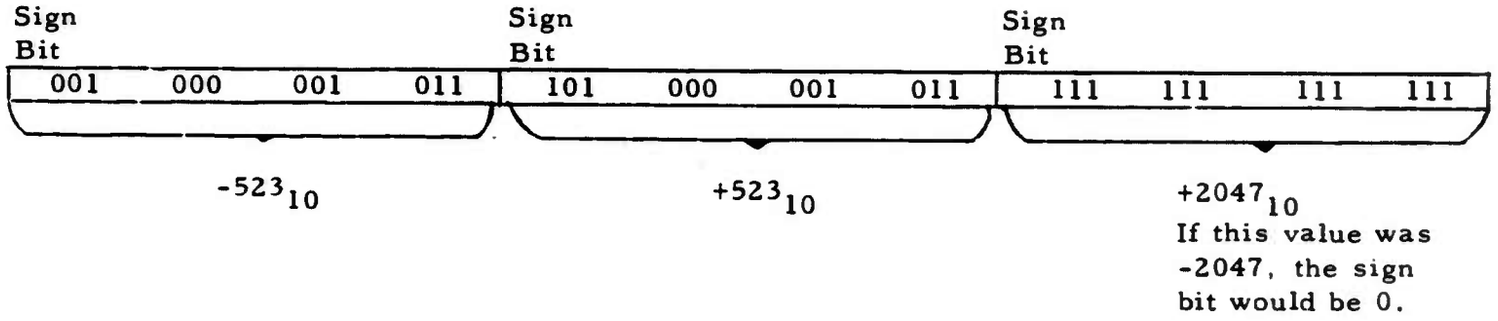


2.3 FORMAT OF ONE DATA WORD CONTAINING THREE DATA SAMPLES FROM THREE DIFFERENT CHANNELS

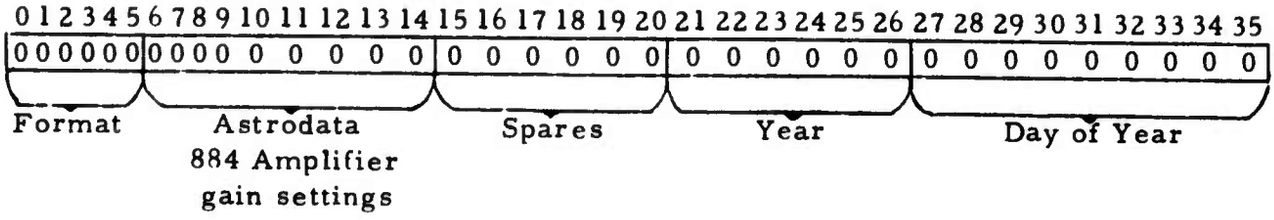


Each sample is represented by 12 bits with the highest order bit indicating the sign and the remaining 11 bits being the data value. Positive and negative values are represented the same with the only difference being the sign bit. If the sign bit is one, the value is positive; if zero, the value is negative.

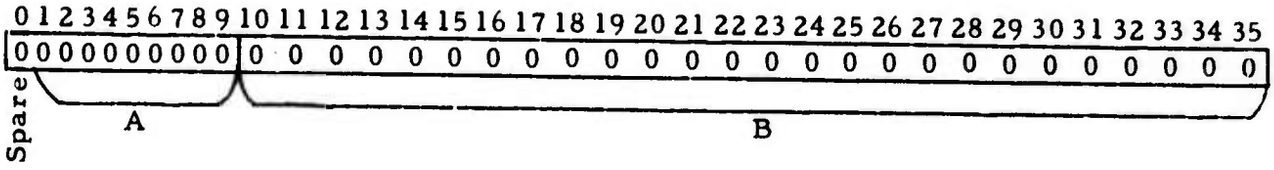
2.3.1 Example of how Actual Samples would be Represented



2.4 FORMAT OF HEADER RECORDER:



2.5 FORMAT OF TIME WORD:



A - Number of five minute intervals past 0000Z when the clock was reset to zero.

B - Number of ms from the time in A to the first data sample of the record. The value of the low order bit is 2^1 instead of the standard 2^0. Therefore, the bit value of B is 2^{26}, 2^{25}, 2^{24} ... 2^3, 2^2, 2^1.

The decoded time word gives the time of the start of the first scan of each record.

CHANNEL ASSIGNMENT

Channel	Seismometer Assignment	Channel	Seismometer Assignment
1	Z1	25	Z25
2	Z2	26	Z26
3	Z3	27	Z27
4	Z4	28	Z28
5	Z5	29	Z29
6	Z6	30	Z30
7	Z7	31	Z31
8	Z8	32	Z32
9	Z9	33	Z33
10	Z10	34	Z34
11	Z11	35	Z35
12	Z12	36	Z36
13	Z13	37	Z37
14	Z14	38	Z60
15	Z15	39	N100SP
16	Z16	40	E99SP
17	Z17	41	Z44LP
18	Z18	42	N46LP
19	Z19	43	E45LP
20	Z20	44	Z51LP
21	Z21	45	N53LP
22	Z22	46	E52LP
23	Z23	47	WWV
24	Z24	48	*STS

*Station Timing System

APPENDIX D

Digital programs written for the evaluation

SEISMIC DATA LABORATORY

Alexandria, Virginia

Digital Computing Section

A. INDENTIFICATION

Title: Mergence of 2 Seismograms Under One Label

COOP Identification: Z148 MERGSEIS

Category: General

Programmer: P.A. Gillespie

Date: September 30, 1967

B. PURPOSE

This program will take any two seismograms from one tape and merge them togehter under a new label with 50 channel identifiers.

C. USAGE

1. Operational procedure: This is a Fortran-63 main program with one subroutine. The subroutine calls two routines from the Monitor Library pack. They are: (1) SKIPREC and (2) SKIPFILE. A data card is needed for each seismogram. If the seismogram number is the same for both seismograms, two data cards must still be used with the same number on each card. The input and output tapes may be either library or subset format.

2. Input card format:

(a) Card requesting the first seismogram.

Column	Parameter	Meaning
1-10	LABEL	Seismogram #
11-13	IN *	Type of input tape
14-16	OUT*	Type of output tape

*The numerical value of IN and OUT has no meaning, but must be non-zero. However, the sign of this numerical value determines the type of tape. A positive number for either IN or OUT or both designates a library tape, whereas a negative number refers to a subset tape.

(b) Card requesting the second seismogram.

This card is identical to the first card, except for the seismogram number, which may or may not be different.

3. Print-outs:

(a) Error messages.

Comment	Cause
TYPE OF INPUT TAPE NOT SPECIFIED-JOB TERMINATED	Cols. 11-13 on either one or both input cards was left blank or a zero used.
TYPE OF OUTPUT TAPE NOT SPECIFIED-JOB TERMINATED	Cols. 14-16 on either one or both input cards was left blank or a zero used.
INTERNAL ERROR IN CALCULATION THE ERROR MAY BE FOUND IN AN IF STATEMENT WITH THE NUMBER (✓✓✓) IN ONE OF THE THREE BRANCHES	A (996) in the parenthesis means that either the first or second seismogram has more than 25 channel identifiers. A (997) in the parenthesis means that the input label does not have the correct number of channels on it.

(b) Printed - Output

After the two seismograms have been merged, the program will print out a message saying this along with the new label. The new seismogram number and the number of channels is a summation of the two input seismogram numbers. The channel

identifiers are consectively in order, taking up two output lines. The fourth line of the label is the event identifier, which is taken from the second seismogram, with the new seismogram number.

4. Space required: 18000

5. Caution to Users:

   (a) The system must have Monitor Library Routines named (1) SKIPREC and (2) SKIPFILE.

   (b) The seismogram numbers on the two input data cards must be in the same sequence as they are on the input tape.

   (c) If the seismogram number is the same for both of the input seismograms, then the same number must appear on both of the input data cards.

   (d) The sign of IN should be the same on both input data cards.

   (e) The sign of OUT should be the same on both input data cards.

   (f) The signs of IN and OUT need not be the same.

SEISMIC DATA LABORATORY

Alexandria, Virginia

Digital Computing Section

A. IDENTIFICATION

Title: Data Converter for TFO Acquisition System Tapes

COOP Identification: M224 TFXARY II

Category: Information processing, conversion

Programmer: J.G. Ferry

Date: 2 January 1968

B. PURPOSE

This program makes a standard library seismogram tape from digital tapes in the format of TFO acquisition system tapes.

C. USAGE

1. Operational Procedure: This is a FORTRAN and CODAP1 main program. A disk file has to be on-line. If more than one input tape is used, a pause, 222, will occur with the next tape reel number on the typewriter.

When a pause occurs with zero in the A-register the tape reel number from output unit 1 should be entered into the A-register in octal.

2. Parameters:

NC, number of channels to be decoded
ST(1), hour of start time
ST(2), minute of start time
ST(3), second of start time
SR, sampling rate in points per second

TL, length of record in seconds to be decoded
IL(1), seismogram number
NREL, input tape reel number
(NCNS(I),I=1,NC) channel numbers to be decoded
(IL(I),I=8,37, second and third seismogram label cards

3. Space required: 19,571 locations plus first four disk file.

4. Temporary storage: none

5. Printouts:

A message is printed on the standard output unit if an end-of-file is encountered on logical unit 3. Program continues, but uses length of data available instead of TL.

6. Error returns: none

7. Error stops: none

8. Input and output tape mountings:

Input tape 3, output tape 2, output tape 1, output tape 7 (BCD), output tape 11 (BCD), output tape 24 (operator comment).

9. Input and output formats:

A. Input

1. Cards:

First card — Format (I5,3F5.2,F10.3,2I10)

Column	Data
1-5	NC
6-10	ST(1)
11-15	ST(2)
16-20	ST(3)
21-30	SR
31-40	TL

41-50	IL(1)
51-50	NREL

Second card — Format (25I3)

Column	Data
1-3	NCNS(1)
4-6	NCNS(2)
7-9	NCNS(3)
.	.
.	.
.	.

Third card — Format (25A3)

Data: second card of seismogram label, IL(8) to IL(32)

Fourth card

Data: third card of seismogram label, IL(33) to IL(42)

NOTE: The four card data deck is repeated for each seismogram.

2. Tape:

The input tape is a digital tape from the TFO acquisition system with a one word header record followed by 2641 words per record and one end-of file at the end of the tape. Each 2641 word record must contain a timing word and 220 scans of 48 channels.

B. Output

1. Output tape on unit 1 is a library seismogram tape.

2. Output tape in unit 2 is a plot tape with internal control.

3. Output tape on unit 7 (BCD) is a listing of the events on the output tape from unit 1.

4. Output tape in unit 11 (BCD) is the first card of the seismogram label and index card for each event on the output tape from unit 1.

10. Selective stops:

At pause 222 the typewriter will display the next reel number to be mounted on input unit 3, or pause 0 for entering the reel number on output unit 1 into the A-register in octal.

11. Time required:

Approximately 1/2 minute per channel for 180 seconds of seismogram length.

12. Accuracy:

Same as input.

13. Caution to users:

Maximum number of channels per seismogram is 25. Channel numbers (NCNS(I)) to be decoded must be between 1 and 48 inclusive. Maximum length of seismogram record (TL) is 800 seconds.

14. Equipment configuration:

7 9 COOP,23551,MUNZL,1/3,0/2/1/S/56/57/E/7=51/11=52/24=54,

30,10000.

15. References:

None

D. APPENDIX

Astrodata Seismic Data Acquisition System Tape Format.

Astrodata Seismic Data Acquisition
System Tape Format

SECTION A. General Description:

The Astrodata Seismic Data is recorded on a 7-track tape with a density of 556 bits/inch. The physical records on the tape consist of:

Header record
IRG (inter-record gap)
Scan record 1
IRG
Scan record 2
.
.
.
Scan record N,
EOF Gap
EOF

where each scan record contains eleven seconds of multiplexed data for 48 channels with a sampling rate of 20 points per channel/per second. More detail is given in Sections B and C below.

SECTION B. Notes:

1. Standard 36 bit word IBM format is used with parity in channel, row, number 7. Parity is odd.

2. Longitudinal parity is taken after the header and each data record.

3. Data samples begin at the start of each scan and consist of two characters, 12 bits, each. Characters are numbered consecutively in each scan: for example, characters 5 and 6 make up the data sample for channel number 3 in each scan.

4. One data record consists of 21, 126 characters.

5. Record gaps appear as follows:

   Record gap (prior to record number 1) = 0.75 in.
   IRG = 0.75 in.
   IOF Gap = 3.5 in.

6. EOF is standard - 17_8

SECTION C. Bit significance in Example Consisting of Two Data Records:

1. Header Record - one word-12 octal numbers-written at the start of each file.

000/001/000/001/010/000/000/000/101/100/110/011 BINARY

0 1	0 1 2	0	0 0 0	5	4 6 3	OCTAL
A	B		C	D	E	

A. format designation; B. Astrodata 884 amplifier gain settings; C. no significance; D. year designation; E. day of year.

2. Data Record - time word written at 11.000 second intervals at the start of each data record. In data record number 1 the time word is:

001/001/000/010/001/011/000/100/101/100/000/101 BINARY

A	B	C

A. No significance

B. Three octal numbers designation the number of five minute intervals past 0000Z when the clock, in C, was reset to "zero." In this example, time was reset at 220_8 or at 1200Z.

C. 26 bits designation the time interval in ms from the time in B. to the start of the first record. Bit value is as follows:

$2^{26}, 2^{25}, 2^{24}, 2^{23}, \text{--------} 2^4, 2^3, 2^2, 2^1$ ms

In data record number 2 the time word is exactly the time word in number 1 plus 11000 ms. A scan is initiated every

50 ms*, therefore, the sample time may be calculated as:

Time specified by the time word + 50 (scan number -1) ms

Data - Data record number 1 - scan number 1:

Characters 1 and 2 have the following significance:

2^0 is equivalent to 4.9 mv.

$+ 2^{10}2^9 2^8 2^7 2^6 2^5 2^4 2^3 2^2 2^1 2^0$

1 0 0 0 0 1 1 1 0 1 0 1 Channel number 1 sampled at the time specified in the time word.

Characters 3 and 4 make up channel number 2 at the same time. Similarly for all 48 channels in first scan.

Data record number 1-scan number 2:

Similar to scan 1, except the sampling time is 50 ms later*.

Data record number 1-scan number 220:

Sample time is the time word plus 10,950 ms.

*Actually, the intervals are: 0,48,100,148,200,248,300,etc.

SEISMIC DATA LABORATORY

Alexandria, Virginia

Digital Computing Section

A. IDENTIFICATION

Title: Analysis of TF037 seismological data

COOP Identification: Z 146 TFOSAN

Category: General

Programmer: P.A. Gillespie

Date: February 29, 1968

B. PURPOSE

To process TF037 data, 20 samples per second, less than 4000 point per channel from a special SDL library tape. This special SDL library tape is made from processing TF037 data through program M224 TFXARYII, and then through program Z 148 MERGSEIS. All data to be evaluated by TFOSAN must follow this procedure. The calibrations to be used as data input must first be processed by Z153 TFOCAL.

C. USAGE

1. Operational Procedure: This is Fortran-63 main program with twelve subroutines. The main program calls five routines from the Monitor Library Pack. They are: (1) LIBDATE, (2) ERASE, (3) SKIPFILE, (4) DISC 63, and (5) ABMAX.

2. Parameters: The deck set-up for TFOSAN to run from a binary deck is as follows:

(a) COOP card - 7 9 COOP, 23551, MUNZL, I/1/0/4/6/S/56/57, 10,1000

(b) 9 EXECUTE, 4, 50, 1

(c) Binary Deck

* (d) Seismogram Card (1)

* (e) Calibration Cards (one for each channel on the input tape)

* (f) Parameter Card (1)

* (g) Filter Coefficients cards (4) with the type of filter in cols. 1 - 4 of the first filter card only.

* (h) Delta time and anomaly cards (5)

* (i) Deletion card (2) (purpose is to prevent a channel from being processed.)

* (j) Type of input tape (1) (this card requires a signed integer constant; if the sign is positive it assumes a library type tape, if it is negative the program assumes a subset type tape)

* See Section C-9 "Input and Output formats" for the details of (d) - (j), and any pertinent restrictions.

2a. Cover Card: Place in Special Operating Instructions section of cover card. "When pause zero occurs place, the number of the tape mounted on logical unit #6, in the A-register in octal form."

3. Space required: 20348

4. Temporary storage required: Disc

5. Printouts:

6. Error returns: Are self-explanatory

7. Error stops: None, except when an error message is printed out.

8. Input and Output Tape Mountings:

(a) Input Data Tape on logical unit #1

(b) Output plot tape on logical unit #4

(c) Output save tape on logical unit #6 (This save tape has all the aligned traces plus two channels, the unphased and phased sums.)

9. Input and output formats:

(a) Input tape (logical unit #1)

The input tape may be either a standard SDL unpacked library tape with a modified label, or a standard SDL Subset tape.

1) The modified label for the standard SDL Library Tape has 50 channel identifiers instead of the standard 25 channel identifiers.

2) The Subset tape will have the standard SDL subset label.

(b) Output tapes

1) Output plot tape on logical unit #4

This tape will plot on the 160A the aligned traces of the raw input data channels, and the four sum traces. They are all plotted to the absolute maximum in the data.

2) Output save tape on logical unit #6

This save tape has all of the aligned trace plus only two of the sum traces, the unphased and phased sum.

(c) Input data cards

1) SEISMOGRAM CARD: (1) card Format is: (I10)

Column	Parameter	Meaning
1-10	ISEIS	To locate the desired seismogram on a tape

2) Calibration cards: There must be one card for each channel on the input tape. Format: (7X,F8.0)

Column	Parameter	Meaning
1-3		The channel identifier for which this calibration is intended
8-15	DMAG	The calibration

3) Parameter Card: (1) card Format: (2A3, 2F3.0, F5.1, F2.0, I5)

Column	Parameter	Meaning
1-3	OPTION*	To filter the individual traces only
4-6	OPTION2*	To filter the sum traces only

* The only values that may be used for these two parameters are the alphabetical words "YES" and "NO".

7-9	REFHR	The hour of the earliest arriving signal
10-12	REFMI	The minute of the earliest arriving signal
13-17	REFSE	The second of the earliest arriving signal
18-19	XPP	The number of seconds for the P-P/2 gait. If a zero is used it will automatically be set for 8 seconds.

20-24	INTAPE	The number of the tape to be mounted on logical unit #1

4) Filter coefficient cards: (4) cards Format is (A4,1X,E15.7,3E20.7/(5X,E15.7,3E20.7))

Column	Parameter	Meaning
1-4	TYPEFILTER	The type of filter being used to filter the data with.
6-20 FILCOA(4 to a card)		FILCOA are the "A" coefficients
21-40		FILCOB are the "B" coefficients
41-60		
61-80		

5) Delta times and anomaly cards (5) cards
Format is: (10(F3.2, F5.3))

Column	Parameter	Meaning
1-3	DT	Delta time for first channel
4-8	AM	Anomaly for first channel
9-11	DT	Delta time for second channel
12-16	AM	Anomaly for second channel
17-19	DT	Delta time for third channel
20-24	AM	Anomaly for third channel
25-27	DT	Delta time for fourth channel
28-32	AM	Anomaly for fourth channel
33-35	DT	Delta time for fifth channel
36-40	AM	Anomaly for fifth channel
41-43	DT	Delta time for sixth channel
44-48	AM	Anomaly for sixth channel
49-51	DT	Delta time for seventh channel
52-56	AM	Anomaly for seventh channel
57-59	DT	Delta time for eighth channel

60-64	AM	Anomaly for eighth channel
65-67	DT	Delta time for ninth channel
68-72	AM	Anomaly for ninth channel
73-75	DT	Delta time for tenth channel
76-80	AM	Anomaly for tenth channel

The next four cards are a repeat of this one.

6) Delection cards: (2) cards Format: 25(A3)

Column	Parameter	Meaning
three at a time	IDUMP	When the channel identifier in this field matches the channel identifier in the same place on the label that channel will be deleted from the processing

NOTE: The channel identifiers on these two cards must be in the same logical position as they are in the label in order to match. For example if the first channel identifier in the label is Z1, be sure to check if the blank is to the left of the Z or the right of the 1 and place in the same position on the deletion card, as this is an A3 format. Otherwise they will not match.

7) Type of input tape: (1) card Format: I10

Column	Parameter	Meaning
1-10	INTAPE*	Type of input tape

* The integer value in this field has no meaning, but must be non-zero. However, the sign of the number determines the type of tape. A positive integer designates a library tape, whereas a negative number refers to a subset tape.

D. METHOD

(1) Detrend

(2) Demagnify

(3) Filter (optional) (4-pole Butterworth - 16 coeff.)

(4) Reverse filtering

(5) Compute RMS on 100 secs of the noise - (N)

(6) Obtain maximum peak-to-peak amplitude of the same 100 sec of the noise, and divide by two N(P-P/2)

(7) Obtain maximum peak-to-peak amplitude of the signal divide by two (S)

(8) Compute the ratio of the signal to the RMS of the noise S/N

(9) Compute the ratio of the signal to the peak-to-peak divided by two of the noise S/N (P-P/2)

(10) Form an unphased sum of each point for all channels

(11) Form a phased sum of each point for all channels based upon the earliest arrival of the signals

(12) One the unphased and phased sum channels are formed, these channels are then processed for steps 3 - 8.

(13) Brennan Weights are computed $\frac{(S/N^2)i}{\sum_{i=1}^{nc}(S/N)i} \cdot \bar{S}$, where

NC = no. of channels; and then applied to each channel.

(14) Unphased sum trace of the channels with the Brennan Weights applied

(15) Phased sum trace of the channels with the Brennan Weights applied

(16) After the Brennan unphased and phased sum traces are formed they are evaluated using steps 3 - 8.

SEISMIC DATA LABORATORY

Digital Computing Section

A. IDENTIFICATION

Title: Subset Library or Subset Tapes

COOP Identification: M219 SUBSETSL

Category: Information Processing

Programmer: R.L. Hawkins

Date: 2 November 1967

B. PURPOSE

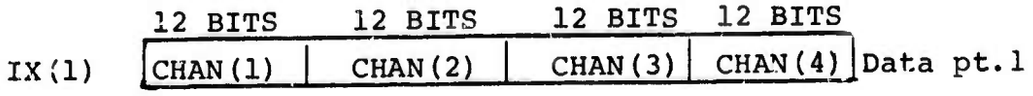
To subset a seismogram/or seismograms contained on the Four standard SDL tapes:

1. Unpacked library tape: the 127 word label record is written first, followed by the data channel records (number of channels $\leq$ 25) with up to 16000 points per channel. After each channel an EOF is written, except for the last channel which has two EOF's.

2. LASA library tape: the same as the unpacked library tape except the last channel may have either a double EOF or an EOF followed by -1.

3. Subset tape: contains a label record of 127 words followed by the data channel records and then one EOF.

4. Packed library tape: is written in the same manner as a subset tape except the data channel records are packed as NC 12 - bit values per word, where $1 \leq NC \leq 4$. That is, for NC = 4 we have,



IX(2)	CHAN(1)	CHAN(2)	CHAN(3)	CHAN(4)	Data pt.2
.	. .	. .	. .	. .	
.	. .	. .	. .	. .	
IX(N)	CHAN(1)	CHAN(2)	CHAN(3)	CHAN(4)	Data pt.N

C. USAGE

1. Operational procedure: This is a F-63 main program and a CODAP-1 subroutine UNPKLTP

2. Parameters:

a. A card containing the plot parameters - ICODE and RANGE

b. A card containing the seismogram number, the start time of the subset, the range or duration time of the subset, a plot switch, a tape switch, and a pause switch.

c. A card containing the ID-codes, such as SPZ,RH,$_{DW1}$,etc., of those data channels desired.

Cards b) and c) are repeated if more than one seismogram is requested.

3. Space required: This program is dimensioned for 16,340 words. a maximum of 16000 data points / channel may be requested from any of the four standard tapes.

4. Temporary storage requirements: none

5. Alarms: none

6. Printouts: For each seismogram request the following is printed out:

1) The output subset label

2) Scale factors for the plots of all data channels. If no plots are requested, no scale factors are printed.

3) The absolute maximum value of each data trace.

7. Error printouts:

1) If the seismogram requested is not on the input tape, the following is printed out, "Seismogram XXXXX not on Tape",

and the next request is processed.

2) If the same channel is requested more than once, the following is printed out "channel XX is requested twice", and the next seismogram request is processed.

3) If the requested ID-code does not equal any of the ID-codes (ID(8)-ID(32)) from tape, the following is printed out, "channel XX not on input tape", and the next seismogram request is processed.

8. Error stops: none

9. Input and output tape mountings:

a) Input tape unit 3
b) Output save tape unit 2
c) Output plot tape unit 4

10. Input card formats:

card 1 Format (F10,I10)

Col.	Data	Description
1-10	RANGE	Vertical height of plots in .01 inches. Be sure that a range is selected which does not cause plots to overlap.
11-20	ICODE	Number of .01 inches between successive data points on plots.

card 2 Format (I10,2(F4,F3,F5),I6,I10)

Col.	Data	Description
1-10	NSELS	Seismogram number
11-14	BHR	Beginning time of subset request in hours.
15-17	BMN	Beginning time of subset request in minutes.
18-22	BSE	Beginning time of subset request in seconds.
23-26	RHR	Range time or duration of the subset in hours.

27-29	RMN	Range time or duration of the subset in minutes.
30-34	RSE	Range time or duration of the subset in seconds.
35-40	LPLOT	Plot switch. If L plot is -1- labeled plots 0- no plot 1- non-labeled plots
41-50	LORS	Subset switch. If LORS is, -1- subset of a packed library tape 0- subset of either an unpacked or LASA library tape 1- subset of a subset tape
51-60		number of channels to plot across.
61-70	IPAUSE	A non-zero value causes the program to pause so another tape of the same type can be mounted. This option is used only when requesting a subset from tapes of the same type (UNPACKED, PACKED, OR SUBSET)

card 3 Format (26A3)

Col.	Data	Description
1-3	IDCHAN(1)	First channel ID-code as written on the label of the input tape.
4-6	IDCHAN(2)	2nd channel ID-code
.	.	.
.	.	.
.	IDCHAN(NC)	the channel ID-code.

The following important features are contained within the program primarily to enable the user to run SUBSETSL with ease. Some of these features are

taken from the SUBSET program because they were found to be extremely useful through usage; however a few like the range time in hours were retained simply because it was felt and consequently discovered that many users of SUBSET had built up a conditional response that the range time in hours is in columns 23-26 of the second data card, even though a range in hours is completely unrealistic at any practical sampling rate.

Important SUBSETSL Features

1) If the beginning time field (columns 11-22 of card 2) is left blank, the origin time of the seismogram on the input is used. For example if the seismogram starts at 10 15 20 Z, the subset will begin at 10 15 20 Z.

2) If the range time field (columns 23-34 of card 2) is left blank, the duration of the subset runs to the end of the seismogram. For example if the seismogram ends at 15 10 00 Z and the beginning time request of the subset is 15 09 00 Z, the subset contains 1 minute of seismic data.

3) If the beginning time request is less than the origin time of the seismogram, the subset will start at the beginning of the seismogram. For example if the user requests a subset start time of 05 10 30.0, but the origin time of the seismogram is 05 10 40.0, the subset will begin at 05 10 40.0.

4) If the range time is larger than that which is available on the seismogram, the duration of the subset runs to the end of the seismogram. For example if the seismogram starts at 10 10 10Z and ends at 10 11 10Z and at range time of 2 minutes is requested, the subset will contain 1 minute of data.

5) There is an automatic pause built into the program to enable the mounting and hence processing of a different type of tape. For example if the user is retrieving seismograms from a packed tape and then wants to process an unpacked tape, the program will pause automatically. However to process two tapes of the same type, the pause flag (column 70 on data card 2)

must be set to a non-zero value.

6) The tape type (pack, unpack, or subset) is printed out on the typewriter for each seismogram processed. This feature allows the operator and user to keep track of what has been processed if program termination occurs.

7) If the user trys to retrieve the same data channel twice or more, this seismogram request will not be processed. Use either the Z120 RODRDATA or Z140 RODBUDSC to obtain the same data channel more than once.

8) Incorrect specification of the ID-codes, such as punching DH1 on data card 3 when you want DW1, results in a waste of computer time and termination of that seismogram request. Make sure that what is punched on data card 3 is truly on the input tape.

9) To retrieve every channel that is written on the input tape for a desired seismogram, merely punch "ALL" in columns 1 - 3 of data card 3.

10) Just about any feasible kind of plotter spacing within the limits of present plotting capabilities is allowed.

a) If the number of plots written across is left blank (column 60 of data card 2), two options exist;

i; Whenever the number of data channels requested is greater than 10, ten channels are written across on the plot tape.

ii; If the number of channels requested is ≤ 10, that number of channels will be written across for plot control.

b. Specify the number you want written across on the plot tape in columns 51-60 of data card 2.

c. If the user is retrieving, for example, one channel from each of ten seismograms and wants these ten channels written across, don't insert a 10 in columns 59-60 of

data card 2. The program control statement is written on tape unit 4 every time a seismogram is processed. Hence the above request results in more plot expectations than availability of plots to fill the logical records. If the user wants to have the above plot presentation or something of the same kind of logic, write plotter switch 11 on and the number of plots across on the plot section of the white job card.

11) The following label will be written (punch - 1 in columns 39-40 of data card 2) before each set of plots corresponding to that seismogram request.

a. SUBSET OF
b. SEISMOGRAM NO XXXXX
c. Heading information from seismogram label like AP-OK 3 JUL 67
d. Channel ID-codes for the plots like ZH RH TH T

12) The scale factors for each plot is printed out.

13) The absolute maximum value of each data channel requested is printed out.

14) A 127 word label for each seismogram is written before the data records. The format is as follows:

IL (1) = seismogram number
IL (2) = the number of data channels
IL (3) = the number of data points/channel
IL (4) = the sampling rate
IL (5) = start time of subset in hours
IL (6) = start time of subset in minutes
IL (7) = start time of subset in seconds
IL (8)-IL (32) = ID-codes of data channels
IL (33) - IL(42) = Identification or pertinent information of the seismogram such as station code (i.e. AP-OK), date of event, name of event, and IL(42) contains the seismogram number presently.

IL(43)-IL(127) = not used presently

11. Selective jump and stop settings: none

12. Timing: Program running time is dependent upon the following factors;

1) The kind of subset requested
For example, if a subset of a packed tape is requested, the fixed point data must be unpacked through the use of subroutine UNPKLTP.

2) Where on the input tape the desired data is written
If the desired seismogram is not at the beginning of the tape, library routines SKIPFILE and SKIPREC must be used.

3) The number of data channels and number of points/channel

4) Whether labeled or non-labeled plots are desired.

13. Accuracy: Single precision

14. Caution to users:

Seismogram must be requested in the same order that they occur on the input tape.

15. Equipment configuration: $\frac{7}{9}$ COOP, 23371,HAWKINS, I/3/0/2/4/S/56/57/E/ 24=54, 60,5000.

16. References: See me and write-ups of Z24 UES SUBSET and PLOTPACK.

BLACKY2

I102 = if 1 - one channel per request
if 2 - two channels per request

NN = ½ total number of filter coefficients to be designed. 0 is no filter is to be designed.

NDEC = Decimator index, 0 or 1 takes every pt, 2 every other point, etc.

NDEG = removes trend of degree NDEG (usually zero)

INTAPE = Input tape - always 3

LAGS = Number of lags. LAGS $\leq$ 501

If I102 = 1

ISW1 2 - semilog plot of power spectra; 1 - no plot

ISW2 2 - linear plot of autocorrelation; 1 - no plot

ISW3 2 - linear plot of power spectra; 1 - no plot

ISW4 - always 1

If I102 = 2

ISW1 2 - semilog plots of power spectra of x + y; 1 - no plot

ISW2 2 - linear plots of autocorrelation x, autocorrelation y, cross correlation xy, autocorrelation yx; 1 - no plot

ISW3 2 - linear plots of power spectra x, power spectra y, co-spectra, qua-spectra; 1 - no plot

ISW4 2 - linear plots of coherency and phase; 1 - no plot

ICODE Plot parameter

IPTAPE Plot tape, always 2.

IAB = if 1 - Subset type input tape with label
if 2 - Subset type input tape with label read on some preceding request.

e.g. - A subset tape contains a label followed by 4 channels (1) to get power spectra only of each channel

CARD 1 I102 = 1, IAB = 1

FORMATS

Card 1 (16I3, 3F10.1)

Column	Data	
3	I102	1 or 2
4-6	NN	
7-9	NDEC	
10-12	NDEG	
13-15	INTAPE - always 3	
16-18	LAGS	
21	ISW1	1 or 2
24	ISW2	1 or 2
27	ISW3	1 or 2
30	ISW4 1 or 2	
31-33	ICODE	plot parameter
36	IPTAPE - always 2	
39	IAB	1, 2, or 3
42	NSAX	1 or 2 (usually)
43-45	NSKIP	
48	NFIL	0 or 1
49-58	RANGE	plot parameter
59-68	CON1	
69-78	CON2	

Following card is needed only if NN 0

FORMAT (5F10.3, I10)

1-10	FB
11-20	FC
21-30	FT
31-40	SP
41-50	RANGE2
51-60	IC2

Following card is needed only if IAB = 3 (16X, I5, F7.1, 5A8)

17-21 N

22-28 DT

29-68 ID

COOP Card

Input - unit 3 - (subset)

Output - unit 2 - plot tape

unit 4 - save tape

Input parameter identical to BLACKY2 with one addition

R - used in smoothing

CARD 2 I102 = 1 IAB = 2

CARD 3 I102 = 1 IAB = 2

CARD 4 I102 = 1 IAB = 2

(2) To get cross correlations of channels 1 + 2 and 3 + 4

CARD 1 I102 = 2 IAB = 1

CARD 2 I102 = 2 IAB = 2

To get cross correlations of a pair of channels, both channels must be under same subset label.

If IAB = 3 - input tape contains no label

NSAX If NSAX = 1 power spectra is written on save tape with Subset type label, I102 spectra and an end of file. If NSAX = 2 period and spectra only are written on tape

NSKIP - number of binary records to skip on input tape. Label a separate record

NFIL - If > 0 input data is filtered with last filter setting read in.

RANGE - plot parameter for linear plots

CON1 - If ≠ 0 each point in first channel is multiplied by CON1

CON2 - If I102 = 2 and CON2 ≠ 0 each point in second channel is multiplied by CON2

SEISMIC DATA LABORATORY

Alexandria, Virginia

Digital Computing Section

A. IDENTIFICATION

Title: AVGSPEC

COOP Identification: Z133 AVGSPEC

Category: General

Programmer: S. Kauder

Date: 19 April 1967

B. PURPOSE

To average spectra computed by program BLACKY2.

C. USAGE

1. Operational procedure: This is a FORTRAN-63 main program. The binary input tape containing the spectra to be averaged is generated by BLACKY2. Any number of jobs on the same or different tapes may be run at one time. The program stops on an end-of-file on the card reader. The plot tape (#4) is written with program control.

2. Parameters:

Card 1 FORMAT(4I10)

Col		Description
1-10	NS	number of spectra to be averaged (maximum of 25. Maximum number of points in spectrum is 501)
11-20	NLOST	number of spectra, if any, to be skipped on input tape.

If NN> 0 the following parameters are needed

FB	beginning frequency (cps)
FC	roll-off frequency
FT	cut-off frequency
SP	sampling rate of data (samples/second), if blank set to 20
RANGE2	plot parameter for filtered data
IC2	plot parameter for filtered data. DATA is plotted if IC2 >0.

IF IAB = 3 The following cards are needed

N	number of points per channel
DT	sampling rate
ID	any 40 character identification

Filter setting needs to be read in only one time. All following requests with NFIL = 1 will be filtered with this setting. Filter may be changed on any request by setting NN> 0.

BLACKY4

FORMATS are identical to BLACKY2 with following exception

Card 1 16I3, 4F5.1

Column

1-48 same as BLACKY2
49-53 RANGE
54-58 CON1
59-63 CON2
64-68 R

BLACKY4 - program control of plotting and writes BCD label before spectra

Col		Description
21-30	INTAPE	input tape unit. If INTAPE is zero, input unit is set to 3. (All input units must be indicated on COOP card)
31-40	NCODE	Determines length of plot (x) if NCODE= 1,100 pts per inch are output.

Second card is needed only when NLOST is nonzero.

Card 2		FORMAT (25A3)
1-3	LOST(1)	Channel ID of spectra to be skipped.
4-6	LOST(2)	
7-9	etc.	

3. Space required: 14000 locations.
4. Temporary storage: none.
5. Printouts: An appropriate heading and the average values are printed.
6. Error returns: none.
7. Error stop: none.
8. Input and output mountings: The input binary tape is generated by BLACKY2. The input unit(s) is assigned by the user by INTAPE. (see section C-2). The output plot tape is #4.
9. Input and output formats: See section C-2.
10. Selective jump and stop settings: none.
11. Timing:
12. Accuracy: N/A
13. Caution to user: none.
14. Equipment configuration:
15. Reference: Program BLACKY2

M E M O R A N D U M

TO: Users of Avgspec

FROM: E. F. Lutz

SUBJECT: Addition to Avgspec Program

DATE: February 15, 1968

Avgspec has been modified to accept a variable NCODE to determine the length of plots (X-AXIS). The card format is now (4I10) with columns 31-40 containing the value of NCODE.

An NCODE of 1 equals 100 ppi, 2 equals 50 ppi, etc. The NCODE value is printed on the output.

EFL:car

APPENDIX I

Calibration parameters

Calibration for TF0-37 on 05 March 1968

Z01	13.015 ctr/mμ
Z02	14.959
Z03	13.321
Z04	14.403
Z05	14.343
Z06	14.280
Z07	14.090
Z08	14.339
Z09	14.156
Z10	15.569
Z11	16.368
Z12	15.107
Z13	12.937
Z14	12.194
Z15	13.439
Z16	15.490
Z17	*14.156
Z18	*14.156
Z19	15.906
Z20	*14.156
Z21	13.642
Z22	10.304
Z23	*13.110
Z24	11.797
Z25	*14.156
Z26	16.951
Z27	16.896
Z28	12.463
Z29	12.176
Z30	12.195
Z31	14.207
Z32	13.668
Z33	13.958
Z34	17.880
Z35	13.089
Z36	16.734
Z37	*14.156

$$Y = \frac{G\ I}{4\pi^2 f^2 m}$$

Y = Displacement in MICRONS

G = Motor Constant in Newtons/Ampere

I = Current in μ amp

f = Frequency in CPS

m = MASS of seismometer in kg

For JM seismometer at 1cps

$4\pi^2 F^2 m = 710.6$

*AVG CAL.-No CAL AVAILABLE FOR THESE SENSORS.

APPENDIX F

Sample output

```
TROBAN PROGRAM                    01 00 A0
   10   35  1.3  TIME OF FIRST PT
   10   37 10.0  MMMMMMMM TIME
INPUT TAPE NO. 15  7140
```

T F 0 3 7 MORRAIDU 96 FEB 68 SHORT PERIOD Z 14379

CH	SIP-P/Z)	RMS	RANGE	S/RANGE	S/RMS	RANGE/RMS	DELTA T	PC 1 FILTER
01	8.76	.91	.00	12.94	48.41	3.19	.69	
02	11.93	.94	.72	16.11	48.16	2.89	.49	
03	9.99	.92	.84	11.82	45.83	3.88	.62	
04	9.97	.91	.76	12.57	46.94	3.58	.68	
05	7.98	.98	.94	14.69	39.91	2.66	.91	
06	DELETED							
07	9.07	.91	.95	16.49	43.95	2.68	.48	
08	12.97	.91	.61	20.75	61.28	2.95	.24	
09	11.92	.93	.86	17.43	50.98	2.92	.49	
10	10.49	.94	.82	12.68	43.21	3.43	.64	
11	8.48	.19	.07	9.73	44.27	4.55	.08	
12	10.46	.94	.84	12.42	43.75	3.52	1.09	
13	9.02	.94	.89	13.34	48.18	2.86	1.11	
14	7.33	.18	.59	12.48	38.58	3.89	1.10	
15	6.92	.19	.48	13.37	34.20	2.56	.93	
16	6.19	.19	.57	10.83	31.81	2.94	.74	
17	6.72	.19	.91	13.27	34.84	2.63	.91	
18	9.97	.92	.68	12.65	39.24	3.10	.28	
19	10.43	.38	.81	12.65	33.99	2.69	.26	
20	10.49	.37	1.12	16.54	58.18	3.93	.0	
21	11.38	.92	1.67	6.76	92.31	7.73	.22	
22	DELETED							
23	11.15	.98	1.96	18.53	48.36	3.83	.61	
24	11.38	.97	1.54	7.32	42.18	5.75	.84	
25	8.91	.17	.62	13.91	48.88	3.54	1.06	
26	8.45	.17	.49	19.21	55.36	2.88	1.28	
27	8.13	.22	.78	11.78	42.98	3.56	1.31	
28	8.11	.92	.66	12.24	34.76	3.08	1.14	
29	6.78	.14	.97	6.98	19.86	2.84	1.36	
30	1.45	.11	.89	3.17	11.42	3.61	1.17	
31	8.38	.28	.75	8.54	31.92	3.69	.98	
32	5.87	.99	.74	6.89	88.39	2.98	.77	
33	6.73	.19	.61	18.87	35.66	3.25	.94	
34	7.73	.19	.99	13.84	98.89	3.13	.31	
35	10.45	.94	.88	14.94	42.93	2.89	.88	
36	19.91	.38	1.28	12.31	41.96	3.41	.84	
37	DELETED							
SUM	312.28	7.73	26.18	420.92	1284.57	115.34		
MEAN	8.18	.93	.77	12.38	87.78	3.39		
VAR	9.24	.88	.88	13.29	188.26	.97		
STD	3.84	.85	.28	3.69	13.78	.98		
U-SUM	1.92	.49	.14	7.83	22.18	3.18		
P-SUM	8.46	.84	.19	56.83	196.23	3.45		
RU-SUM	1.38	.89	.15	9.51	28.28	2.97		
RP-SUM	8.59	.85	.14	61.53	184.39	3.88		

	SIGNAL (DB)	RMS (DB)	NOISE (DB)	S/N (DB)	S/RMS (DB)
U-SUM	-19.11	-13.88	-14.93	-4.91	-4.64
P-SUM	-.71	-14.44	-14.28	13.24	14.31
RU-SUM	-16.49	-13.93	-14.48	-2.29	-2.94
RP-SUM	-.58	-13.76	-14.83	13.93	13.77

```
THE SAVE TAPE NUMBER IS 1154
THE FOLLOWING IS THE LABEL ON THE SAVE TAPE
   14379        38        3749      28.88 1V 35  1.3
01 02 03 04 05 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 23 24 29 26 27
28 29 30 31 32 33 34 35 36US PS
T F 0  3 7    MORRAIDU          05 FEB 68   SHORT PERIOD Z              14379
```

APPENDIX G

JM frequency response

SHORT PERIOD - (JOHNSON MATHESON)

Seismometer free period: 1.25 sec
Seismometer damping: 0.510
Galvanometer free period: 0.333 sec
Galvanometer damping: 0.650

T	f	%	Norm	Max	Normalized	Min
5.0	0.2	10	0.0120	0.0132		0.0108
2.5	0.4	7.5	0.0950	0.102		0.0878
1.25	0.8	5	0.685	0.720		0.651
1.0	1.0	0	1.00	1.00		1.00
0.67	1.5	5	1.52	1.60		1.44
0.5	2.0	5	1.90	2.00		1.80
0.33	3.0	7.5	2.12	2.28		1.96
0.25	4.0	12	1.87	2.09		1.64
0.167	6.0	20	1.15	1.38		0.920
0.125	8.0	25	0.64	0.800		0.480
0.1	10.0	25	0.370	0.463		0.278

Unclassified

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13. ABSTRACT

Beamforming of the TFO-37 array reduces the rms of the noise up to 14 db over an average single sensor, and the signal/noise improvement approaches 14 db also depending on the band pass filter used. The signal loss after beamforming and summing is approximately 1 db. Power spectra was also performed on the noise after summation as well as on individual traces and showed a 15 db reduction at 1 cps; this is an improvement of N over an average single element.

Maps, digital programs, instrument frequency response, etc. are included.

14. KEY WORDS

Beamforming
TFO-37 Array
Signal/Noise Ratio
Noise Reduction

Unclassified

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